Optimisation of a vertical spray boom for greenhouse spraying applications

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Summary

The European Crop Protection Association (ECPA) and CLO-DVL joined forces in a project to stimulate a safe use of pesticides in Southern European countries. CLO-DVL optimised a method with mineral chelates to evaluate deposition tests. This quantitative method to evaluate spray deposits and to check spray distributions is used to assess two novel spraying techniques.

Deposition tests with water-sensitive paper and mainly with the manganese and molybdenum chelates as tracer elements were performed with a manually pulled trolley and a motorised vehicle both equipped with vertical spray booms. Filter papers were attached to the tomato and pepper plants at several heights to obtain an indication of the spray distribution in the crop.

Particular attention was paid to the effect on the spray distribution of the vertical nozzle distance (35 cm vs. 50 cm) and the spray distance to the crop.

The tests proved that a nozzle spacing of 35 cm delivers a much better spray distribution than one of 50 cm. The optimal spray distance for flat fan nozzles with a spray angle of 80° and a nozzle spacing of 35 cm is about 30 cm.

Introduction

The general objective of the 'ECPA safe use initiative' is to stimulate a safe use of pesticides in Southern European countries through the introduction of novel, innovative spray equipment and techniques and by teaching the users how to handle, to clean and to maintain their equipment.

This research project deals with novel spray equipment with vertical spray booms for the application of crop protection products in

greenhouses. Tests were carried out with a manually pulled trolley and a motorised vehicle 'Fumimatic'. Deposition tests on plant leaves were performed under field conditions to determine the influence of spray distance and nozzle spacing.
The main objective was to look at the effect of the vertical nozzle spacing (35 cm vs. 50 cm) and the spray distance to the crop on the spray distribution.

Materials and methods

The spraying equipment
The *Fumimatic* (Fig. 1) is a concept for agricultural spraying in greenhouses and in open field. The standard Fumimatic is equipped with eight flat fan TeeJet XR8003 nozzles and two vertical spray booms with a nozzle spacing of 50 cm.
The manually pulled *trolley* is a very simple machine fed with a hose via an external pump and tank. It also has two vertical spray booms with a nozzle spacing of 50 cm and eight flat fan TeeJet XR8003 nozzles installed with an offset angle of 7°.
For the experiments, new spray booms were constructed with a reduced nozzle spacing of 35 cm (twelve nozzles) for the trolley as well as for the Fumimatic. This proposal to reduce the nozzle spacing was presented in the Dutch paper 'Application Techniques in Glasshouses in The Netherlands' (1994). Before executing the spraying tests, both machines were subjected to a detailed technical test (Ministerial Decree on the Mandatory Inspection of Sprayers in Use in Belgium, 23/08/2002).

The greenhouses
The experiments were performed under field conditions in two greenhouses, one with tomato and one with pepper plants, both very popular crops in Southern Spain. The number of running metres of plants for each greenhouse (tomatoes: ± 4000 m/ha, peppers: ± 5000 m/ha) and the driving and walking speed with the Fumimatic (± 2 m/s) and the trolley (± 1 m/s) were calculated for each greenhouse to determine which nozzle type and which pressure had to be used to spray a particular volume per hectare.

Water-sensitive paper

Water-sensitive paper provides a very fast, visual, qualitative, clean and cheap method for checking spray distribution and droplet sizing. It was used as a first indicator for the spray distribution to determine the optimal spray distance.

Strips of water-sensitive paper were attached on vertically placed wooden poles. The distance between the spray boom and the target (in this case the wooden pole) was adjusted to achieve the best possible spray distribution with the trolley, for the 35 cm as well as for the 50 cm nozzle spacing. A strip of water-sensitive paper was positioned on the ground to determine the deposition on the ground.

A volume of about 300 l/ha was sprayed to get a good visual assessment of the spray distribution on the vertically placed water-sensitive paper. Spray distribution evaluation was done visually.

After optimising the distance between the spray boom and the target, the settings were tested under field conditions in the tomato crop. Water-sensitive paper strips were attached to the tomato crop at several heights to check the distribution in a real crop.

Chelates method

The Agricultural Research Centre in Ghent (CLO-DVL) has already gained some experience with the use of mineral chelates as tracers on filter paper collectors, a technique to evaluate spray deposition and distribution quantitatively (De Moor, 2002). The products used, perform similarly as pesticides under the same conditions. Manganese (Mn) and molybdenum (Mo) chelates were used for these experiments. These products are normally used as horticultural leaf fertilisers, hence their use in normal concentrations does not damage the crop. The concentrations of manganese and molybdenum in the tank were about 1000 mg/l. The Mn-chelate was used for all the sprayings with the 50 cm nozzle spacing, the Mo-chelate for the 35 cm nozzle spacing. Before each spraying, a tank sample was taken to know the exact concentration. Inductively Coupled Plasma analysis (ICP) was used to determine the amount of metals on the filter paper collectors after extraction with 14N nitric acid (HNO_3). Schleicher & Schuell filter papers (7.6 x 2.6 cm) were used throughout. Earlier experiments proved that there is no interference between the minerals Mo and Mn, which is important for the ICP analysis (De Moor, 2002).

In each greenhouse, two random crop rows were selected with a given distance between them. One row was used for the sprayings with the trolley, the other for the sprayings with the Fumimatic. Hence, each row was sprayed twice, once with a 50 cm nozzle spacing and once with a 35 cm nozzle spacing using the same collectors at the same locations. This made a total of eight sprayings.
The expected spray volumes for the applications were 500 l/ha for peppers and 750 l/ha for tomatoes. So, the total spraying volumes for two runs amount to approximately 1000 l/ha and 1500 l/ha. Such large volumes are normally used in Spanish horticulture but had to be avoided in one spraying in our experiments because of the risk of run-off. This would compromise the accuracy of the chelates method.
The collectors were placed at five different heights on the leaves of the plant. At each height, two filter papers were placed, one at the upper and another at the lower side of the leaves. In one row six plants are selected as repetitions (Fig. 2). In total, 240 collector samples with two chelates had to be analysed.

Results

Effect of the spray distance on the spray distribution

As described above, water-sensitive paper was used to optimise the spray distance to obtain the best possible spray distribution. Normally, the pressures used in Spanish horticulture are very high, the nozzle spacing is 50 cm, the spray angle used is 80° and the distance between the crop and the spray boom is about 30 cm. Theoretically, Spanish growers use single overlap (30 cm spray distance, 80° spray angle). However, actual practice differs from the theoretical situation:

- The actual spray angle of 80° does not hold for long distance
- For vertical spray booms, the spray pattern is distorted by the influence of gravity

Probably, more overlap is necessary to be sure that the entire crop is uniformly covered. In most cases, double overlap is impracticable because of the small distance between the rows. Besides, it is possible that in case of large spray distances, there are too many losses to the soil. The tests with water-sensitive paper were executed to optimise the spraying distance.
For both nozzle spacings, different sprayings were performed with spray distances from 20 to 40 cm. The tests demonstrated that the

optimal spray distance is about 30 cm for a nozzle spacing of 35 cm as well as for a nozzle spacing of 50 cm. If the spray distance is larger, the spray pattern becomes distorted because of the influence of gravity and there are more spray losses to the ground. For smaller spray distances, the advantage of overlap is lost and non-covered zones were detected especially for the nozzle spacing of 50 cm.
For a spray distance of 30 cm, the spray distribution for the 50 cm nozzle spacing seemed less good compared to the spray distribution for a nozzle spacing of 35 cm.
Before doing the quantitative tests with the chelates on the real crop, a test was carried out with water-sensitive paper strips, attached in the tomato crop at heights of 60, 100, 140, 180 and 220 cm. Spray coverage of the water-sensitive paper strips was visually good.
In conclusion, the tests with the water-sensitive paper strips demonstrated that a good spray distance for vertical spray booms is about 30 cm. Hence, a spray distance of approximately 30 cm was used for the deposition tests with the chelates.

Effect of the nozzle spacing (35 cm vs. 50 cm) on the spray distribution

The sprayed volumes on the underside of the leaves compared with those on the topside were very low and irregular, i.e. about 10% for the tomato crop and about 4% for the pepper crop. This demonstrates that penetration into the crop is low and that the crop structure influences the spray penetration. Peppers are a very closed crop with almost vertical leaves. Tomatoes on the contrary are more open and the leaves are less vertical. There were no indications that the nozzle pressure affects crop penetration within the normal working pressure range of a flat fan nozzle.
The results of the deposition tests (measured concentrations of Mo and Mn after extraction with 20 ml nitric acid) for the topside of the leaves in peppers with the trolley are represented in figures 3a and 3b. The results with the Fumimatic were similar. The better spray distribution for the 35 cm spray boom is clearly perceptible. The Tukey multiple comparison procedure was used to investigate whether this hypothesis could be proved statistically even with the limited number of measurements. A 95% confidence interval for the deposition at each height was calculated. Figures 4a and 4b represent the calculated 95% confidence intervals for the spray volumes at the

topside of the leaves at different heights, this time for the Fumimatic. Again, results with the trolley were similar. Figures 5 (trolley) and 6 (Fumimatic) represent the same facts, this time for the deposition tests in the tomatoes.

A good indicator of the spray distribution is the coefficient of variation (standard deviation divided by the average) of the measured concentrations on the filter papers in the crop (table 1). A small coefficient of variation means a good overall spray distribution.

For the topside of the leaves, the spray distribution with the 35 cm spray boom is better than with the 50 cm spray boom. This conclusion is valid for the peppers and the tomatoes as well as for the Fumimatic and the trolley. With the 50 cm spray boom, there were some non-covered zones at the topside of the leaves.

The spray distribution with the trolley is slightly better than with the Fumimatic. This is due to the fact that it is rather difficult to maintain a constant spraying distance because of the difficulty to drive straight with the Fumimatic.

The very large confidence intervals (Fig. 4a and 6a) for a nozzle spacing of 50 cm indicate that the amount of spray liquid is very irregular, even at a constant height. For a nozzle spacing of 35 cm, these intervals are three to four times smaller, this means that at a constant height, a constant amount is sprayed.

Besides a large variation in spray volumes at a constant height, there is also a significant difference between the different heights for the 50 cm nozzle spacing. For example, with the Fumimatic in peppers with a nozzle spacing of 50 cm (Fig. 4a), at 1.4 m height the sprayed volume is significantly more (confidence level: 95%) than at 1.1 and 1.7 m. Although the confidence intervals are much smaller for the 35 cm spray boom, there is no significant difference between the different heights.

Discussion

The trolley and the Fumimatic are new innovative spraying techniques in Southern Spain. Compared with the traditional spray gun, it is possible with these techniques to obtain a better spray distribution. In addition, these techniques may increase productivity, reduce labour costs and decrease operator exposure. Reducing the vertical nozzle spacing from 50 cm to 35 cm is a simple and cheap adaptation to obtain a much better spray distribution in the crop. The

optimal spray distance for a nozzle spacing of 35 cm is about 30 cm for flat fan nozzles with a spray angle of 80°. On a vertical spray boom the nozzles should be installed with an offset angle of 7°. In this way the spray cones overlap in the crop and the effect of spray boom movements is reduced.

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Fig. 1. The Fumimatic and the manually pulled trolley, both equipped with vertical spray booms

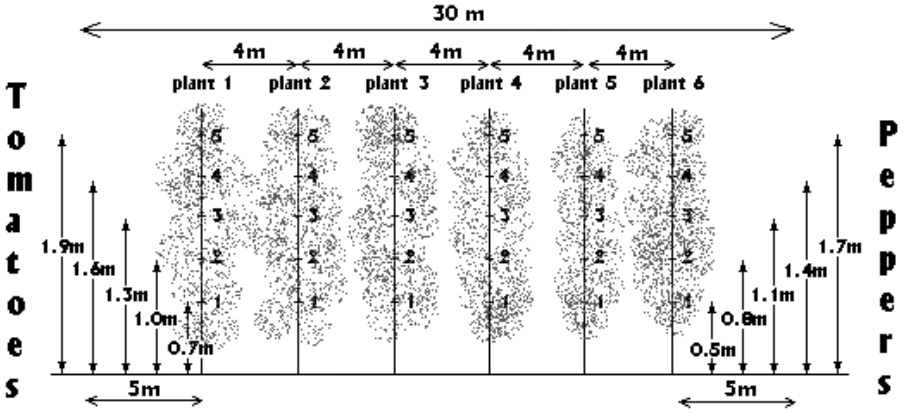

Fig. 2. Positioning of the filter papers in a crop row

Table 1. Coefficient of variation for the different sprayings

	nozzle spacing	
	35 cm	50 cm
trolley-peppers	0.20	0.50
Fumimatic-peppers	0.38	0.71
trolley-tomatoes	0.26	0.60
Fumimatic-tomatoes	0.40	0.76

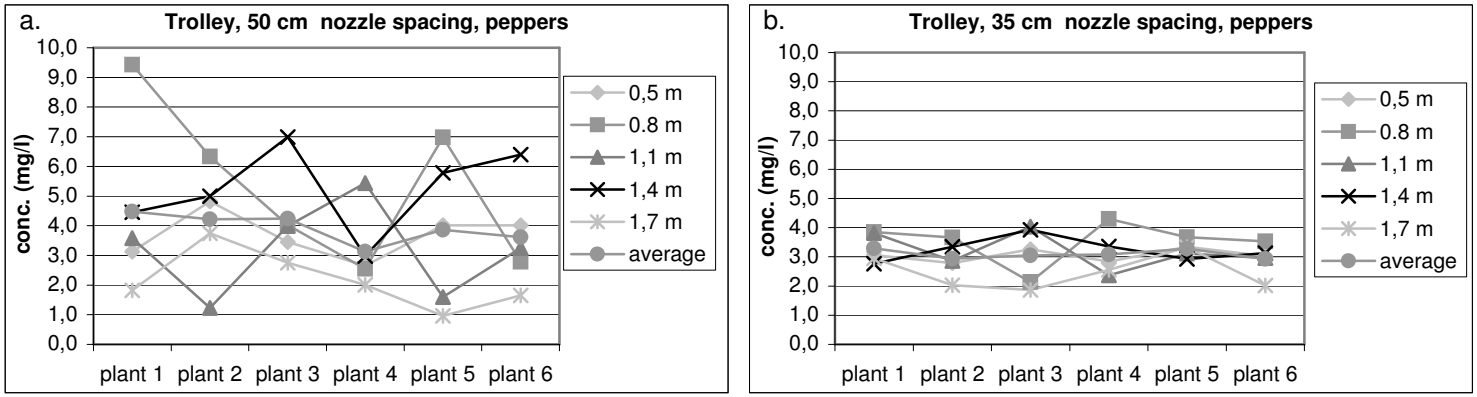

Fig. 3. Results of the deposition tests in the pepper crop with the trolley
(a) 50 cm nozzle spacing (b) 35 cm nozzle spacing

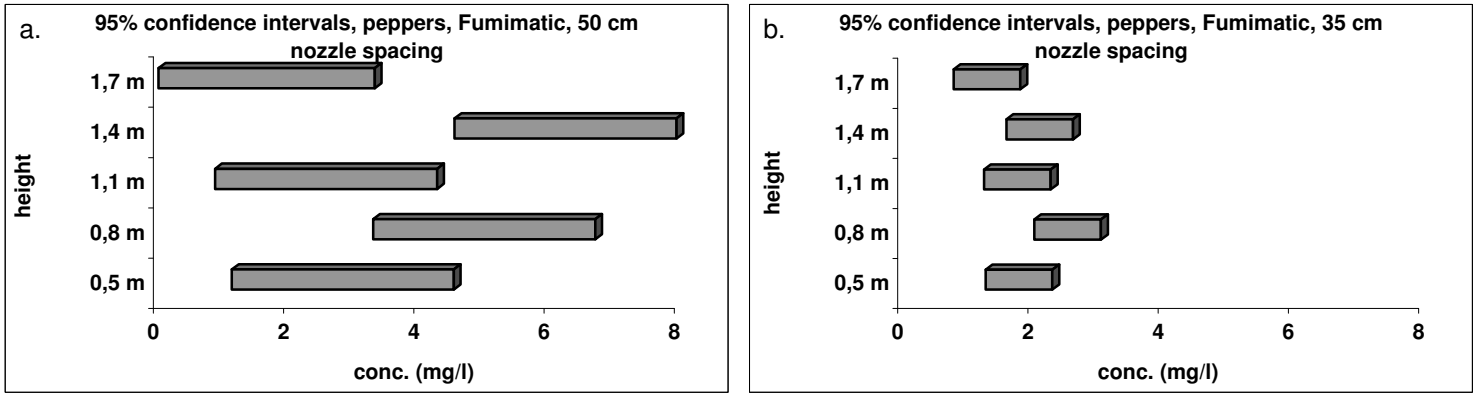

Fig. 4. 95% confidence intervals for the deposition on the topside of the leaves in peppers using the Fumimatic

(a) 50 cm nozzle spacing (b) 35 cm nozzle spacing

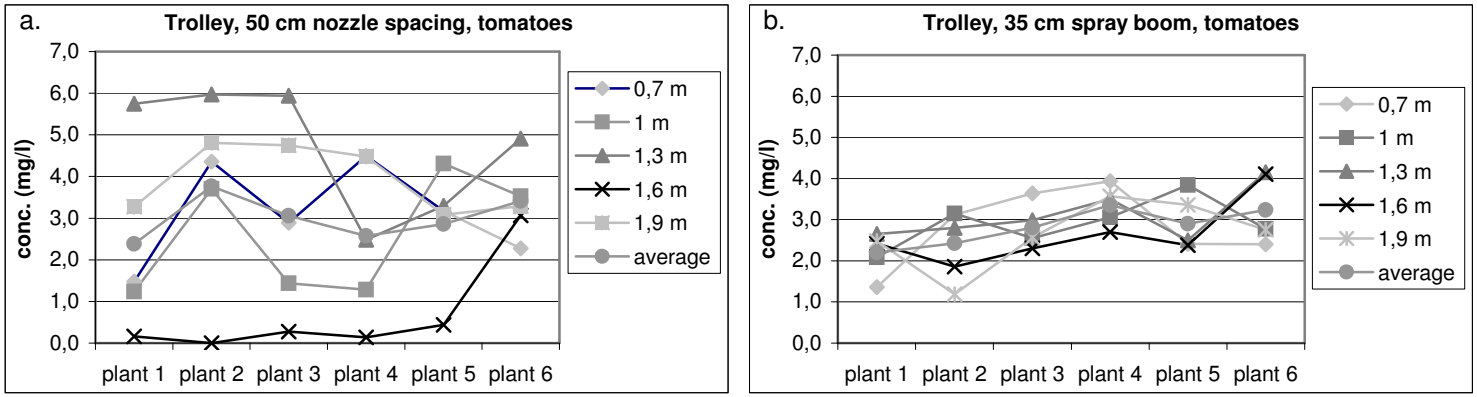

Fig. 5. Results of the deposition tests in the tomato crop with the trolley
(a) 50 cm nozzle spacing (b) 35 cm nozzle spacing

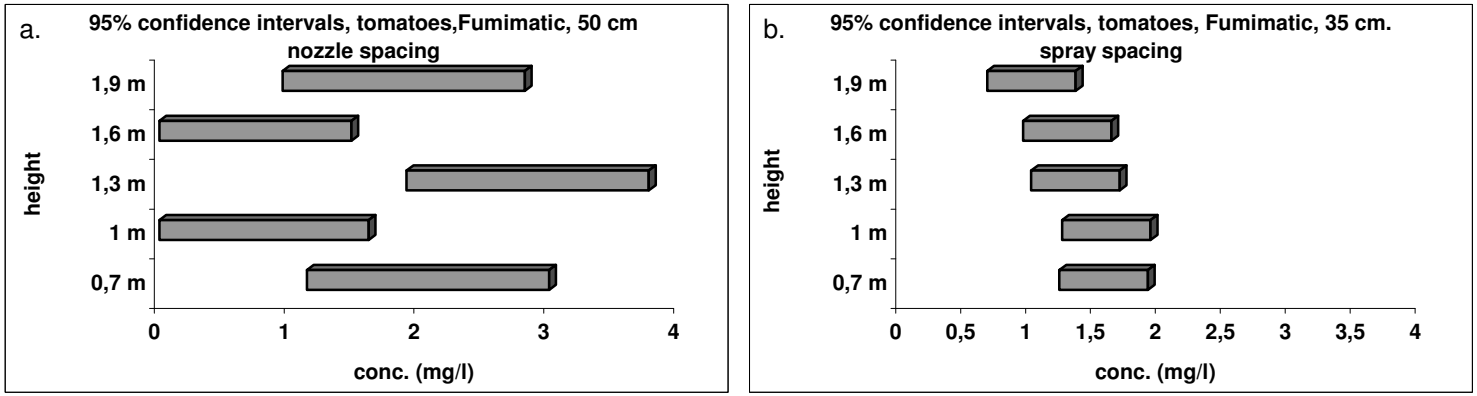

Fig. 6. 95% confidence intervals for the deposition on the topside of the leaves in tomatoes using the Fumimatic

(a) 50 cm nozzle spacing (b) 35 cm nozzle spacing